RADIOLOGY

DIAGNOSIS–IMAGING–INTERVENTION

Volume 3

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DRUG DOSAGE

The authors and publisher have exerted every effort to ensure that drug selection and dosage set forth in this text are in accord with current recommendations and practice at the time of publication. However, in view of ongoing research, changes in government regulations, and the constant flow of information relating to drug therapy and drug reactions, the reader is urged to check the package insert for each drug for any change in indications and dosage and for added warnings and precautions. This is particularly important when the recommended agent is a new or infrequently employed drug.

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vances, it should be released until it reaches the original level where it is again pinned to prevent further advancement. When the catheter tip reaches a satisfactory position, the guidewire is removed, the catheter is flushed, and a test injection is made. There will often be a large amount of slack in the aortic arch, which must be removed by slow pulling.

The use of large catheters in which the curve must be reformed (*e.g.*, H3H, Simmons 1-3) demands a different technique. These catheters are used most frequently for selective injections into tortuous left common carotid arteries, but they may also be used for right innominate and left subclavian artery injections. Once the curve has been reformed in the aortic arch, the catheter should be positioned in the ascending aorta. Gentle pulling and turning, usually without the guidewire, will usually hook the origin of the right innominate or left common carotid arteries. The right innominate artery can usually be hooked easily, and gentle pushing of the catheter will remove the tip from this vessel when it is not the vessel of interest. By turning the catheter to flatten it in the aortic arch and then gently pulling and simultaneously turning the curve upward, the origin of the left common carotid artery can usually be hooked. The catheter should then be pulled gently to slightly advance the tip. The large primary curve allows the catheter to sit satisfactorily in this proximal position, and no further advancement with guidewire is necessary. It should be remembered that pushing these catheters will remove them from the vessel, whereas pulling will advance the tip.

For routine cases, the left vertebral artery can usually be selectively catheterized with the No. 5 French catheter used for the carotid injections. The catheter may be placed in the origin of the left subclavian artery directly or may be placed first in the origin of the right innominate or left common carotid arteries. With the curve turned slightly to the left, the catheter is gently pulled until the tip pops into the origin of the left subclavian artery. A test injection of contrast should be performed from this location to visualize the origin of the left vertebral artery. If the origin is not stenotic or excessively tortuous, the straight 0.038-inch guidewire can be advanced into the proximal vertebral artery with subsequent advancement of the catheter. If the origin is involved with atherosclerotic disease or is excessively tortuous, the tip of the catheter may be placed in the subclavian artery just distal to the vertebral artery origin with the curve aligned along the axis of the subclavian artery. An injection from this point with compression of the arm by a blood pressure cuff will usually give good filling of the left vertebral artery circulation.

In patients with more tortuous vessels, the subclavian artery may have an acute angulation from the aortic arch similar to that of the left common carotid artery. Selective vertebral artery catheterizations may be difficult and dangerous in these patients. Catheters with greater torque control and curves that will more easily enter the subclavian artery (e. H1H, H3H) will often be needed.

Pressure injectors can be used for all diagnos film runs, and the clear plastic tubing between catheter and the syringe must be checked caref for air bubbles when connections with the cathe are made. If there is any vibration or poor backfl of blood when flushing or connecting the injector, catheter tip is lying against the vessel wall and m be repositioned. An injection should not be ma when there is no return of blood through the cathet since vascular damage may result.

The catheter should be withdrawn from the vess into the aortic arch immediately after the film ru unless the vessel was very difficult to catheterize there is suspicion of a technical malfunction. Wh all appropriate films have been viewed, the cathet can be removed. The femoral artery is then co pressed with the fingers of the left hand. The sk incision should be in view to assess for continu bleeding caused by an inadequate compression. T bleeding must be stopped, but the pulse should not occluded. Ten to twenty minutes is adequate co pression in most patients, and the skin is th cleansed and sprayed with disinfectant. No dressi is used on the puncture site, since leaving the si uncovered allows better identification of potential v nous oozing, rebleeding, or enlarging hematoma. T size of significant hematomas should be marked the skin to allow later assessment of enlargement.

Postangiography care includes monitoring of vit signs, pedal pulses, and the puncture site every 1 minutes for 1 hour, every 30 minutes for 2 hours, an every hour until stable. Complete bed rest with bending of the leg is ordered for 6 hours, and th operator must be notified in the event of any compl cations.

DIRECT PERCUTANEOUS CAROTID PUNCTURE

At one time, direct carotid puncture was the mo common approach to angiography. It has been r placed in most institutions by the femoral cereb approach and is now usually reserved for those p tients in whom catheterization is difficult or impo sible. The neck on the side of interest is appropriat shaved, prepared, and draped. With the patient s pine, the neck is moderately extended with one two pillows under the shoulders. An inflatable rubb bag can be used for this purpose so that the head an neck do not have to be excessively repositioned aft the needle is in place.

The 18-gauge Potts–Cournand puncture needle commonly used, often with a metal immobilizatio rake.[12] This device prevents needle motion, whic may cause arterial damage. By bending the flexib metallic handle up or down, the needle tip can b positioned safely in the artery. The tip usually nee to be elevated slightly to remove it from the poster arterial wall, and this is done by depressing the rake

of the x-ray beam around the head is most important for best results in decreasing scatter.

Subtraction

Selected subtraction films can be useful to remove overlying bone densities from vascular images, particularly near the base of the skull. Opacification of various structures, such as tumors, small arteries, veins, and the capillary phase of normal cortex, is enhanced. Small tumors or vascular malformations may also be detected more easily. The patient must be immobilized, since the slightest motion between the mask and the contrast image will degrade the final subtraction print.

ANGIOGRAPHIC INSTRUMENTATION

Prior to the performance of any type of cerebral angiography, the procedure and its risks should be reviewed thoroughly with the patient the night before; his chart should be reviewed as well. Clear fluids should be ordered for the meal immediately prior to angiography, and 10 mg diazepam (Valium) given orally 30 to 45 minutes before the procedure, is usually adequate for sedation. Children require general anesthesia. Atropine may be used to decrease saliva production, swallowing, and carotid bulb excitability, although this is less important with catheter angiography. Intravenous fentanyl citrate (Sublimaze) can be used for sedation in very apprehensive patients. The placement of an intravenous line for the duration of the procedure is optional. Vital signs are monitored as appropriate during angiography.

FEMOROCEREBRAL CATHETER ANGIOGRAPHY

The first cerebrovascular catheterization was performed accidentally by Radner[6] in 1947 when his catheter entered the right vertebral artery during an attempted cardiac study from the right arm. Seldinger's description[7] of a simple technique for insertion of femoral catheters led inexorably to the development of femorocerebral catheter angiography as a standard procedure. Although materials and catheters have changed over the years, the techniques have remained remarkably similar to the descriptions of earlier investigators.[8–11]

Femorocerebral catheterization has many advantages over other instrumentation choices for cerebral angiography. The technique is easy to learn and causes less patient discomfort than other methods. If complications occur at the puncture site, such as arterial trauma, thrombosis, or distal embolization, the sequelae are usually less dangerous to the leg than to the brain. All cerebral vessels can be studied using one arterial puncture.

The patient lies supine on the angiography table with the arms supported on either side next to the body. The right inguinal area is suitably shaved, prepared, and draped. The routine angiographic [illegible] and equipment have been described above. In [illegible] dren under 10 years, we use No. 4 French, [illegible] catheters with 0.032-inch guidewires. For adult[illegible] der 40 years, a No. 5 French white polyethy[illegible] catheter, steam-shaped by the operator, and a 0[illegible] inch straight guidewire are all that is usually [illegible] quired. In patients 40 to 50 years and older, a 0[illegible] inch J-shaped guidewire is used to advance [illegible] catheter up the aorta, and a 0.038-inch straight gu[illegible] wire should be used for selective catheterization[illegible] older patients, catheters with more complex,[illegible] formed curves as well as stiffer Torcon cathe[illegible] should be close at hand in case of excessive elo[illegible] tion and tortuosity of the arch vessels.

The femoral artery is palpated 2 cm to 3 cm be[illegible] the inguinal ligament, which can be approximated [illegible] a line joining the anterior–inferior iliac spine with [illegible] symphysis pubis. The puncture site should there[illegible] be at or slightly above the skin crease in most [illegible] tients. If the puncture is made too high above [illegible] crease, the femoral artery may be difficult to con[illegible] and the danger of retroperitoneal hemorrhage ex[illegible] If the puncture is too low, similar difficulty in co[illegible] trolling the artery will exist, and the distance [illegible] tween the skin and the artery will be lengthene[illegible] which may limit maneuverability of thin cathete[illegible] The overlying skin and adjacent soft tissues sho[illegible] be infiltrated with local anesthetic. A small skin in[illegible] sion is made and the femoral artery is palpated w[illegible] several fingers of the left hand.

The 18-gauge Potts–Cournand needle can be us[illegible] for femoral punctures and has many advantages. T[illegible] short bevel is not likely to cause intimal dissectio[illegible] The hollow, sharp inner needle and cannula perm[illegible] small amount of blood backflow when the vesse[illegible] entered, and a single-wall puncture can be easily [illegible] tected. The needle is held at an angle 30° to 45° to [illegible] skin and is slowly advanced with the right hand un[illegible] it approaches the anterior wall of the vessel a[illegible] transmitted pulses are felt. The artery is punctu[illegible] by a sharp thrust of the needle. The stylet is wi[illegible] drawn, and, if a double-wall puncture has been mad[illegible] the hub of the cannula is depressed and then slo[illegible] withdrawn until brisk arterial backflow is seen. A[illegible] proximately 20 cm of guidewire is then gently [illegible] serted. If the operator is alone, the thumb and in[illegible] finger of the left hand can be used to hold the gui[illegible] wire while the other three fingers press on the pu[illegible] ture site to prevent hematoma formation. The ri[illegible] hand can then be used to remove the needle ca[illegible] nula, wipe the guidewire with a moist Telfa pad, a[illegible] thread the catheter up along the guidewire. The [illegible] of the guide should protrude out the proximal end [illegible] the catheter before advancing both up the aorta. A[illegible] ter the catheter and guide have been positioned in [illegible] descending aorta, the guide is removed and wip[illegible] and the catheter immediately flushed with hepar[illegible] ized saline.

The guide should not remain in the catheter f[illegible] more than 90 seconds at any time during the proc[illegible]

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Techniques and Risks of Cerebral Angiography

DAVID M. PELZ
ALLAN J. FOX
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Cerebral angiography has been one of the more important methods for the investigation of neurologic disease since the first direct carotid injection of sodium iodide by Moniz in 1927. The increased availability of computed tomography (CT) has reduced the number of angiograms now performed; however, angiography is still essential for the accurate assessment of patients with aneurysms, arteriovenous malformations (AVMs), and cerebral atherosclerosis. In patients with tumors it is often necessary to have a detailed picture of the vascular anatomy in order to assess the major source of blood supply, the exact location (*i.e.*, intra-axial versus extra-axial), and the potential for preoperative embolization. Although it is an invasive procedure, conventional film/screen angiography is still the standard with which all other vascular imaging modalities are compared. When performed properly by an experienced operator, cerebral angiography is a safe procedure that provides definitive information in many disease processes.

This chapter will briefly review the techniques of carotid angiography, including descriptions of the necessary equipment and representative radiography. The techniques of femorocerebral catheterization as well as direct puncture, axillary, and retrograde brachial angiography will be discussed. Complications and morbidity unrelated to contrast material will be reviewed, and the final section will deal with digital subtraction angiography as it applies to neurologic diagnosis.

CAROTID ANGIOGRAPHY

EQUIPMENT

X-Ray

The neuroangiography suite should be equipped with a modern three-phase generator capable of 1000 mA to 1500 mA. Biplane filming may be performed for each injection if two x-ray tubes and film changers are available. The tubes should be equipped with 0.6-mm focal spots, with 0.3-mm focal spots available for magnification. Film changers must be able to provide at least four exposures per second. A fluoroscopic imaging system is required. A movable angiography table with a suitable headboard should permit easy technician access for positioning of the patient's head. A power injector with a capacity of at least 45 ml to 60 ml should be used for all injections. For the lateral views, par-speed screens are routinely used, but high-speed screens may be necessary for the anteroposterior (AP) runs to decrease exposure and reduce fogging when biplane filming is performed. For the kilovolt range used in cerebral angiography, 100-line, 8/1 grids are most appropriate.

Angiography Trays

Basic angiography trays vary greatly but most should contain the following: k-basins, cutting board and scalpel blade for catheter modifications, towel clips, and scissors. Four syringes for flushing solution and three syringes for contrast material should be provided. These syringes should be of different sizes for easy identification. Sterile towels and drapes, a 10-ml syringe for local anesthetic, and a skin preparation set are also necessary.

For routine catheter neuroangiography, we add a straight white No. 5 French polyethylene catheter, 0.038-inch straight and J-shaped teflon-coated guidewires, Telfa guidewire wipes, and an 18-gauge Potts–Cournand puncture needle. A plastic steridrape with a hole for the femoral artery puncture site is provided. At our institution, a closed system by which the scrub assistant can draw up contrast for test injections and flushing solution on the angiography table is used. This incorporates four sterile infusion sets with a male-female adaptor.

Drugs

Two 500-ml bags of 0.9% normal saline are needed. Heparin (1000 units–3000 units) should be added to each bag.[1] One bag may be used to continuously flush the catheter through a three-way stopcock, and the other is used to provide syringes of flushing solution via the infusion set and male-female adaptor. A 150-ml bottle of contrast material can be hung from an IV pole and connected to the adaptor by infusion tubing to provide contrast for test injections. A 50-ml bottle of contrast is used to fill the power injector. Conray 60* is commonly used for selective cerebral injec-

* Meglumine iothalamate.

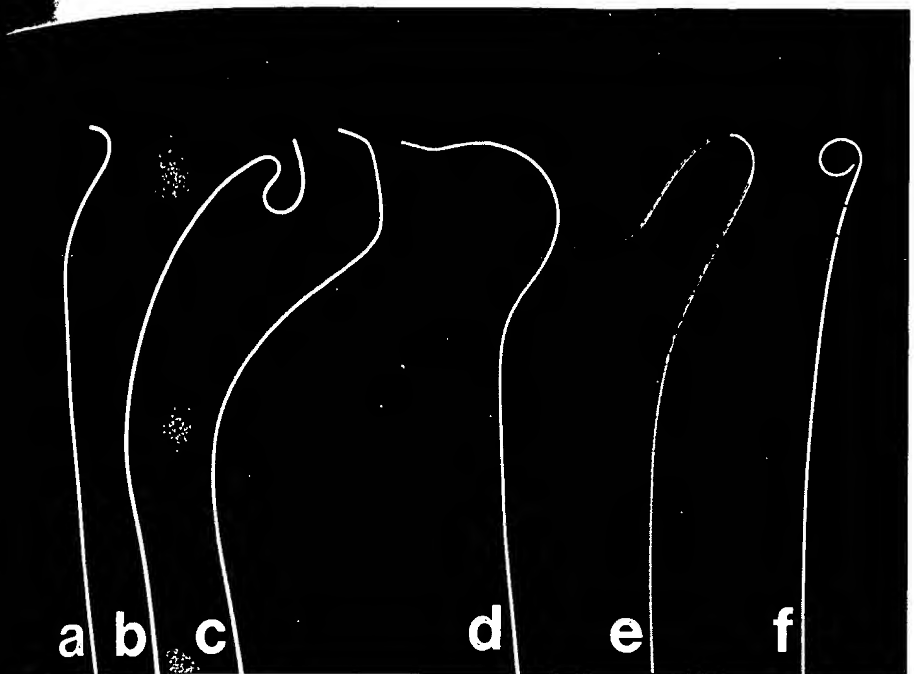

Fig. 1. Representative polyethylene catheters used in femorocerebral angiography. **a.** No. 5 French white polyethylene catheter, shaped by the operator with a small curve suitable for young patients. **b.** No. 5 French HN4 (Cook Corporation, Bloomington, Illinois) preshaped with a more complex curve. **c.** No. 6.5 French Torcon H1H useful for left vertebral angiography. **d.** No. 6.5 French H3H. **e.** No. 6.5 French Simmons. **f.** No. 6.3 French pigtail catheter for aortic arch injections.

...AL. For the basal view, a sponge is placed under ...houlders and the head is extended as far back as ...sible with the vertex touching the table. The tube ...ngled cephalad 30° and centered on the thyroid ...tilage. Aneurysms of the middle cerebral and an...rior communicating arteries are shown particularly ...ll in this view.[3]

...OTID BIFURCATIONS. Coned down AP and lat...l views of the neck may be used to demonstrate ...erosclerotic disease.

...TIC ARCH. With the patient supine, the head ...trunk are rotated 45° to the right. The right poste... oblique (RPO) view is best for separating the ...gins of the great vessels.

...Runs

...ND LATERAL HEAD. For selective common ca...d artery injections, 10 ml/sec for a total of 12 ml is ...monly used. This is usually decreased to 8 ml/sec ...total of 10 ml for selective internal carotid injec.... A representative filming sequence would be 2 .../sec for 3 seconds, 1 film/sec for 4 seconds, and 1 ...every 2 seconds for 2 seconds. This 12-film se...nce demonstrates the arterial, capillary, and ve... phases well in most cases. An injector delay of ...econd provides a subtraction mask. For selec... vertebral angiograms the injection rate is 7 ml/ ...or a total of 9 ml. If the catheter cannot be selec...y advanced into the vertebral artery, it may be ...d in the subclavian artery just distal to the origin ...vertebral artery. An injection of 8 ml/sec for a ...of 14 ml, with cuff compression of the ipsilateral ...will give good filling of the vertebral circulation in most cases. Selective external carotid studies are performed at a rate of 3 ml/sec for a total of 5 ml or 6 ml.

OBLIQUES AND SPECIAL VIEWS. Short runs such as 2 films/sec for 3 seconds are usually adequate to show the arterial phase only in patients with aneurysms.

Technique

Routine views should be taken at 70 kV to 75 kV, since this approximates the K-edge of iodine. For the basal view, 85 kV may be necessary. Cornmeal bags or suitable bolsters will be necessary to equalize densities in the neck.

Stereo Views

Stereo views are performed using two consecutive runs separated by a 6° tube shift. They may be done in any position, although the lateral is used most commonly.

Magnification

Normally there is approximately 10% magnification present with routine angiography. Radiographic magnification is based on increasing the object–film distance while keeping the target–film distance constant. For magnification two times the original, the head should be midway between the tube and film. Small focal spots (0.3 mm) are needed, and the grid should be removed to increase definition (the air gap is sufficient to handle scatter radiation). Sharp coning

to minimize the risk of thrombus formation. Each time the guide is removed from the catheter, a double flush should be performed with syringes of heparinized saline flushing solution. When the guide is removed, the first syringe is attached to the three-way stopcock, and with the syringe held upward, the plunger is withdrawn until there is return of blood. This removes any small blood clots or air bubbles that were introduced at the time of catheter and guide insertion. This syringe is then discarded and a second flush syringe is attached to the stopcock. With plunger end upward, the Luer-Lok end is tapped with the fingers while withdrawing the plunger to remove any small air bubbles within the stopcock itself. When a small amount of blood return is seen, the plunger is depressed, the catheter flushed, and the stopcock is closed while pressure is still maintained on the plunger. Similarly, whenever contrast is to be injected manually, a small amount of blood should first be withdrawn into the syringe before the injection is made. This technique, performed after each guide insertion, will prevent distal embolization of thrombus or small air bubbles. When the catheter has been flushed, a continuous heparinized saline drip can be connected to the catheter via the three-way stopcock. A careful check for small air bubbles must be made before the infusion is connected to the catheter. Alternatively, repeated double flushes every 90 seconds may be performed if the continuous flushing system is not used.

The vessel of greatest clinical interest should always be examined first. This will ensure that the most important information will have been obtained if the study cannot be completed as a result of subsequent equipment failure or patient complication.

Assuming that the right common carotid artery is to be examined first, the catheter can usually be advanced easily into the ascending thoracic aorta without a guidewire. Often the No. 5 French white catheter must first be filled with a small amount of contrast material to be seen at fluoroscopy, since it is only faintly radiopaque. In children and young adults, the great vessels are oriented vertically and the catheter tends to enter the left subclavian artery. A C-shaped guidewire will allow the catheter to cross the aortic arch.

When the catheter reaches the ascending thoracic aorta, gentle rotation of the catheter will turn the curve upward, and the origin of the right innominate artery can be easily hooked. A small test injection of contrast will show the origin of the right common carotid artery on fluoroscopy. A 0.038-inch straight guidewire is then advanced into the right common carotid artery with the tip lying approximately 2 cm below the carotid bifurcation. Catheter advancement is sometimes facilitated by turning the patient's head to the contralateral side. The catheter is advanced smoothly until the tip reaches the end of the guidewire, which is held or "pinned" with the right hand. Normally the catheter should not be advanced up cranial vessels without a guidewire in place and should not project above the tip of the guidewire. The guide is then removed and a double flush performed. A test injection of contrast material to confirm satisfactory catheter location below the bifurcation is then made. The carotid bifurcation can usually be seen on AP fluoroscopy by rotating the patient's head slightly. The aortic arch should briefly be visualized to check that there is no slack in the catheter. The catheter may flip out of the vessel when a pressure injection is made if slack is present.

For selective internal carotid artery injections, the guidewire should then be advanced to the C2 level, making sure that the bifurcation has been clearly visualized (preferably with lateral fluoroscopy or with the head turned) to avoid dislodging atherosclerotic plaques.

To selectively catheterize the external carotid artery, the tip of the catheter should be positioned just below the carotid bifurcation with the curve directed anteriorly. Lateral fluoroscopy is helpful for optimal visualization of the bifurcation. The guide can then be advanced into the trunk of the external carotid artery and the catheter gently advanced over the guide.

To catheterize the left common carotid artery, the catheter is then pulled slowly down the right common carotid and right innominate arteries with the curve pointing slightly to the left. With gentle pulling, the catheter can be seen to pop out of the right innominate artery into the origin of the left common carotid artery. Again, it often helps to turn the patient's head to the contralateral side. The same steps that were performed on the right side are then repeated.

In older patients, the great vessels are more tortuous and leave the aortic arch at more acute angles. Catheters with more complex curves will often be required. The right common carotid artery can usually be catheterized in the manner described above, but the left common carotid artery may be difficult to enter. The right innominate artery is hooked, and gentle pulling of complex curved catheters (*e.g.*, HN4*) will usually hook the origin of the left common carotid artery. The acute angulation of this vessel may prevent advancement of the guidewire, which may buckle the catheter and cause it to flip out of the artery. If may be difficult to slide the catheter over a guidewire that has been successfully advanced into this vessel. Once the origin of the left common carotid artery has been well hooked, all excess slack must be removed from the catheter in the aortic arch. A more flexible guidewire such as the Willson movable core wire may be needed to advance up a tortuous artery. The guide should be advanced well up the vessel to the level just below the bifurcation. With the guide pinned by an assistant, the catheter can be rotated several times to remove slack and then it should be slowly advanced over the guide. The tip of the guidewire is visualized fluoroscopically, and if it starts to descend in the vessel as the catheter ad-

* Cook Corporation, Bloomington, Illinois.